Salinity, the Global Water Cycle and SPURS

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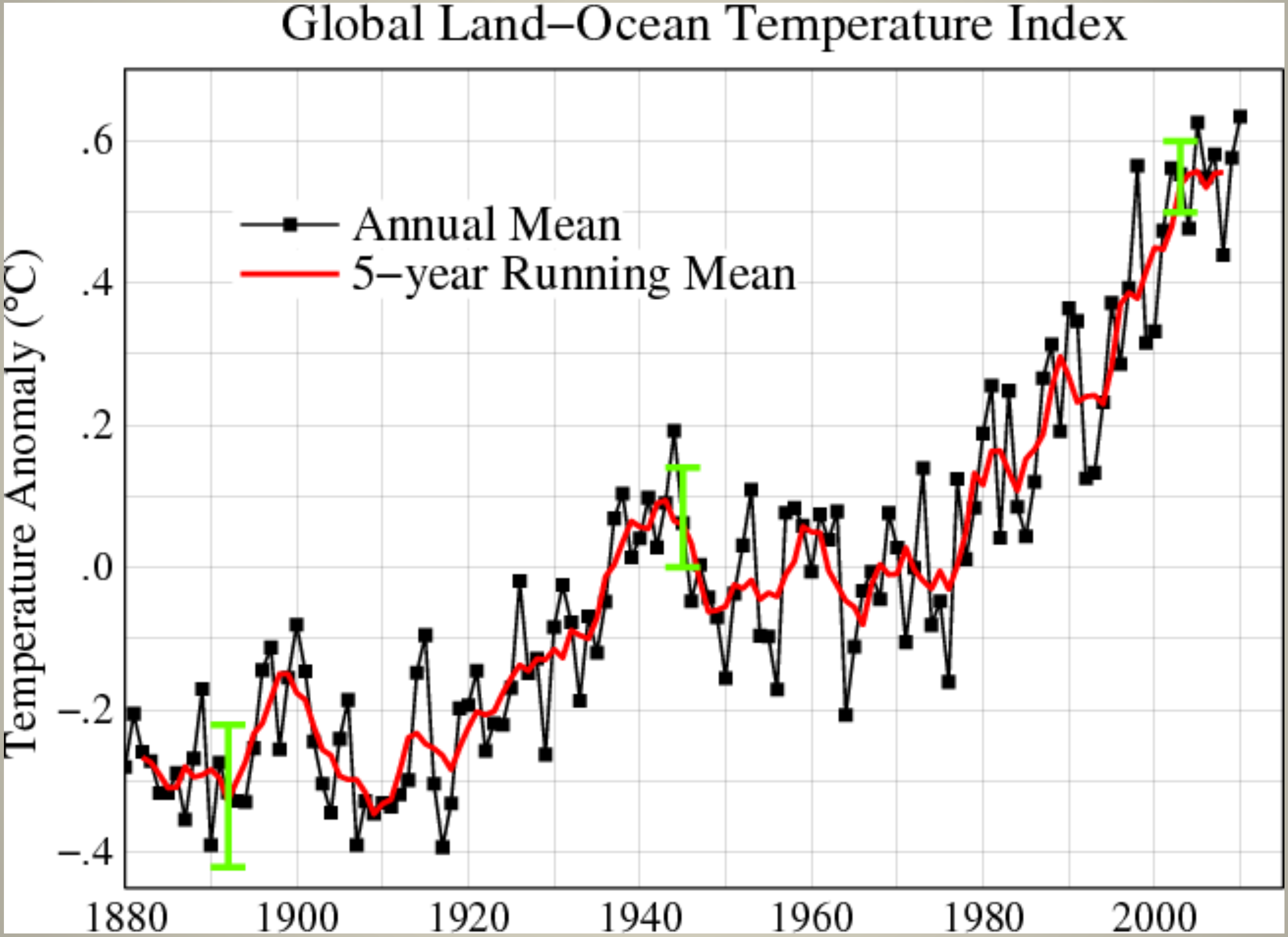
WHOI

February 22, 2011

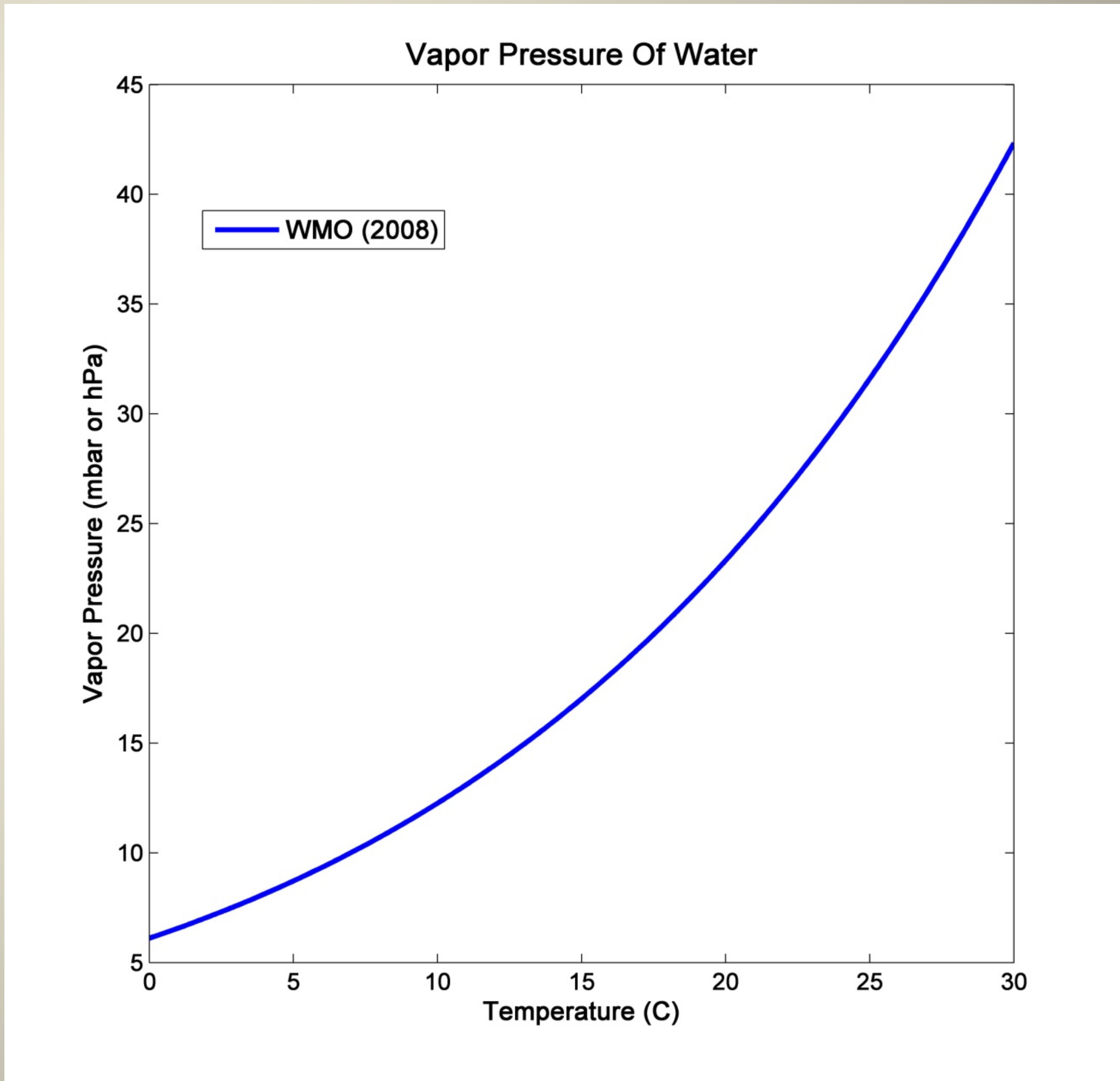
Surface air temperatures are rising



from GISS Surface Temperature Analysis

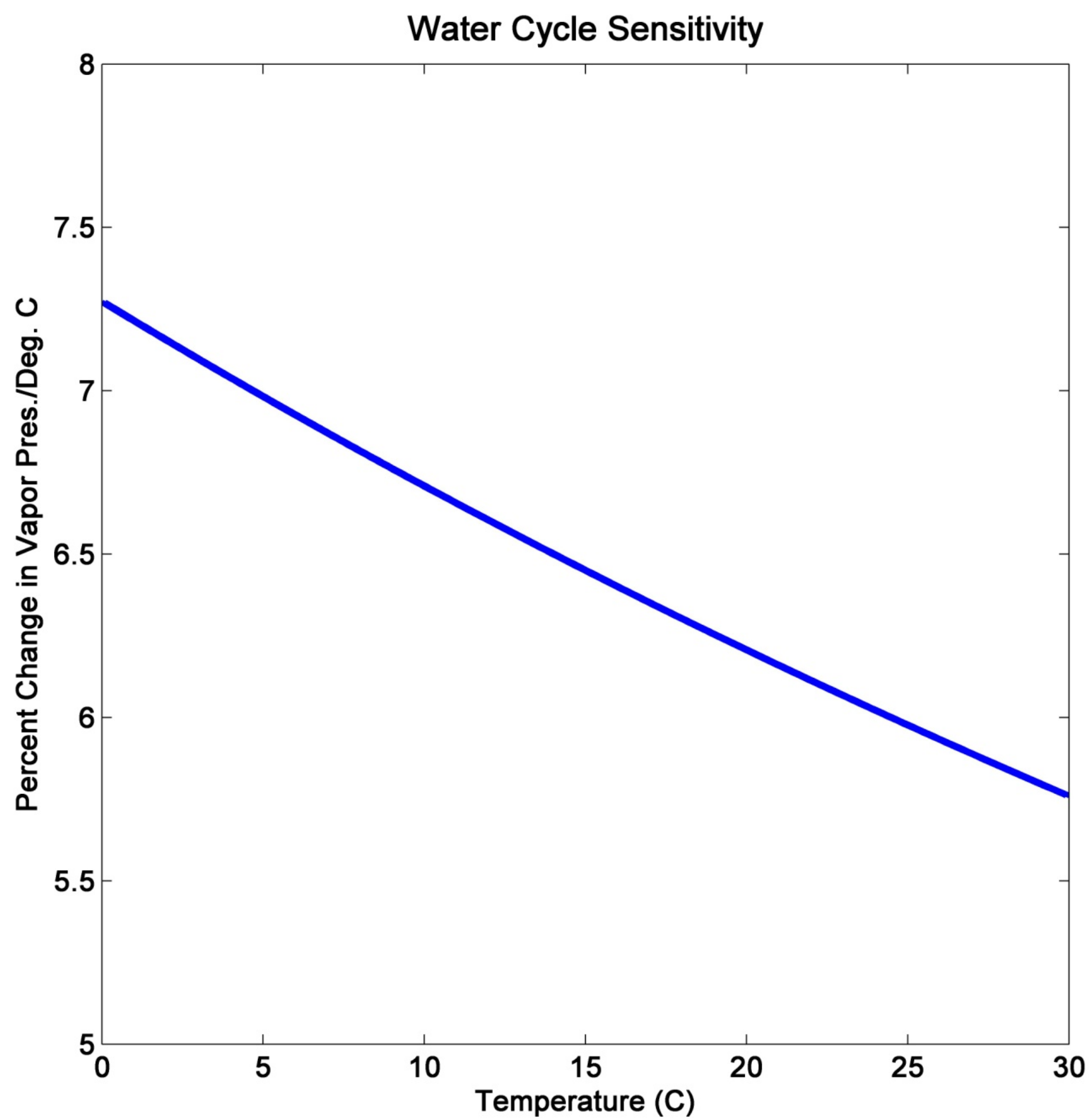
The Water Cycle Will Accelerate With Global Warming

- **A warmer atmosphere will carry more water vapor, because of the exponential increase of vapor pressure with temperature.**
- **An enhanced water cycle will change the distribution of salinity in the upper ocean.**

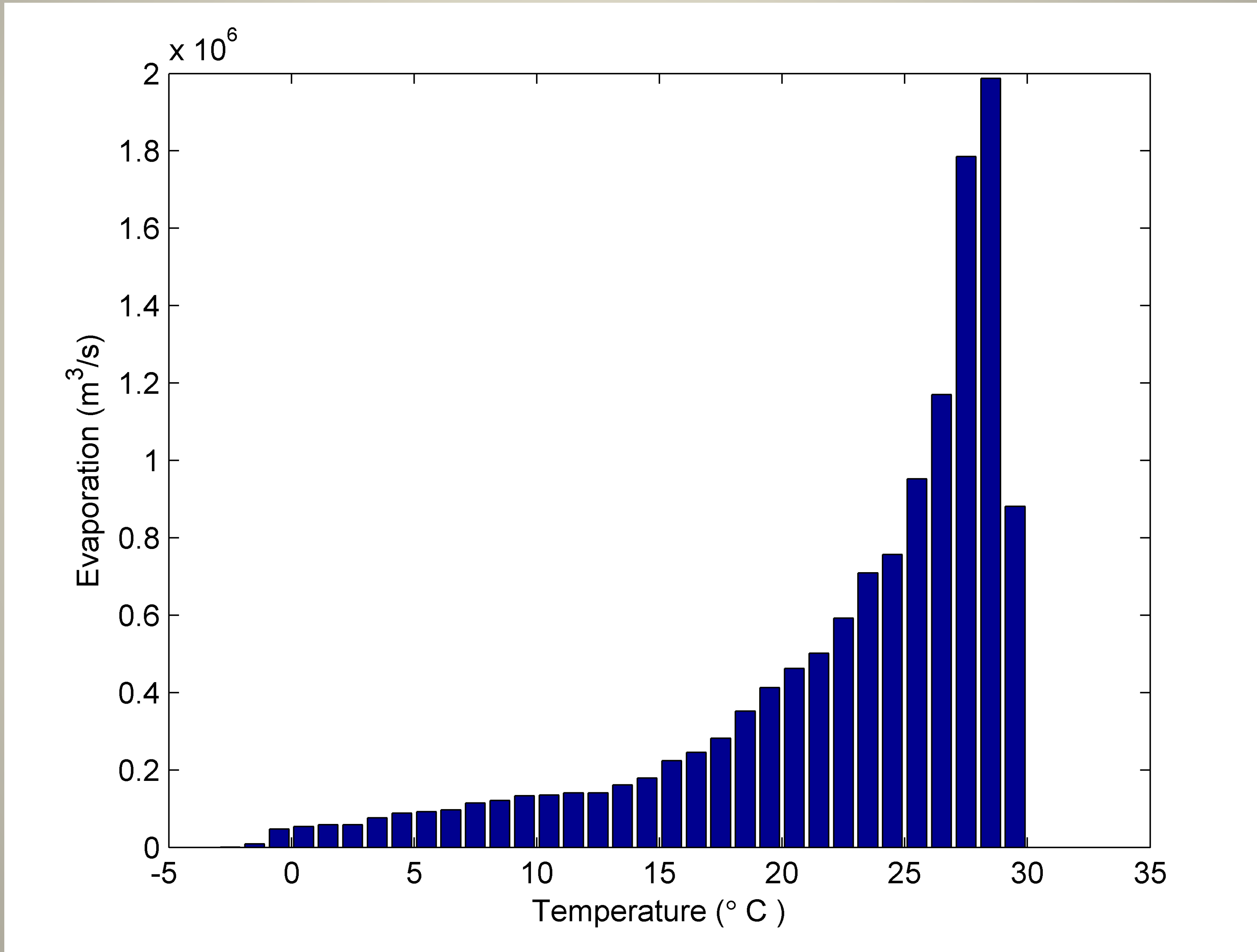


Water Cycle Sensitivity (percent/deg C)

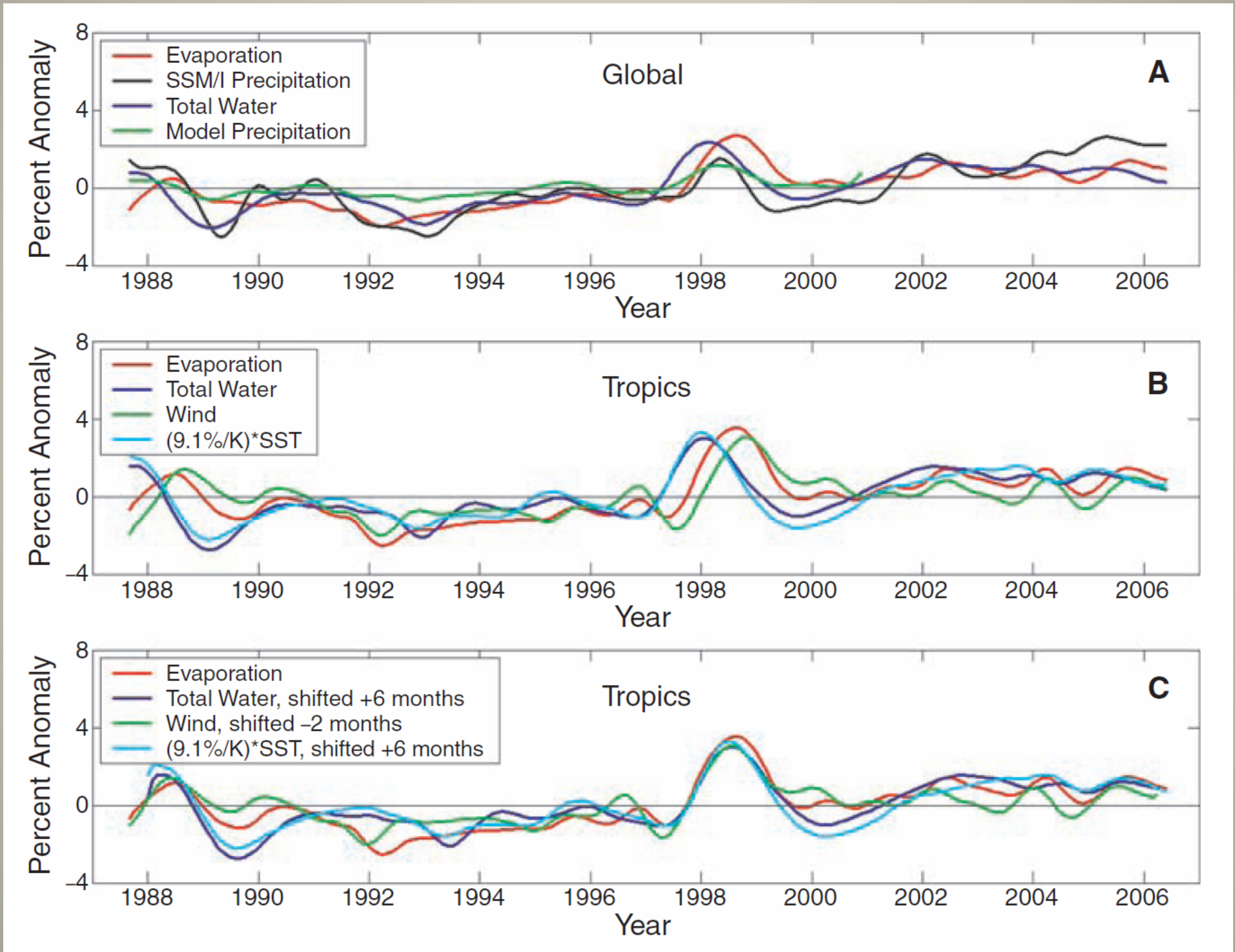
According to Clausius-Clapeyron, the vapor carrying capacity of the atmosphere will increase with temperature at ~7%/deg C, but IPCC models all display an intensification of the WC of less than 2%/per degree! (Held and Soden, 2005)
Data on E, P and SSS suggests that the models are wrong!



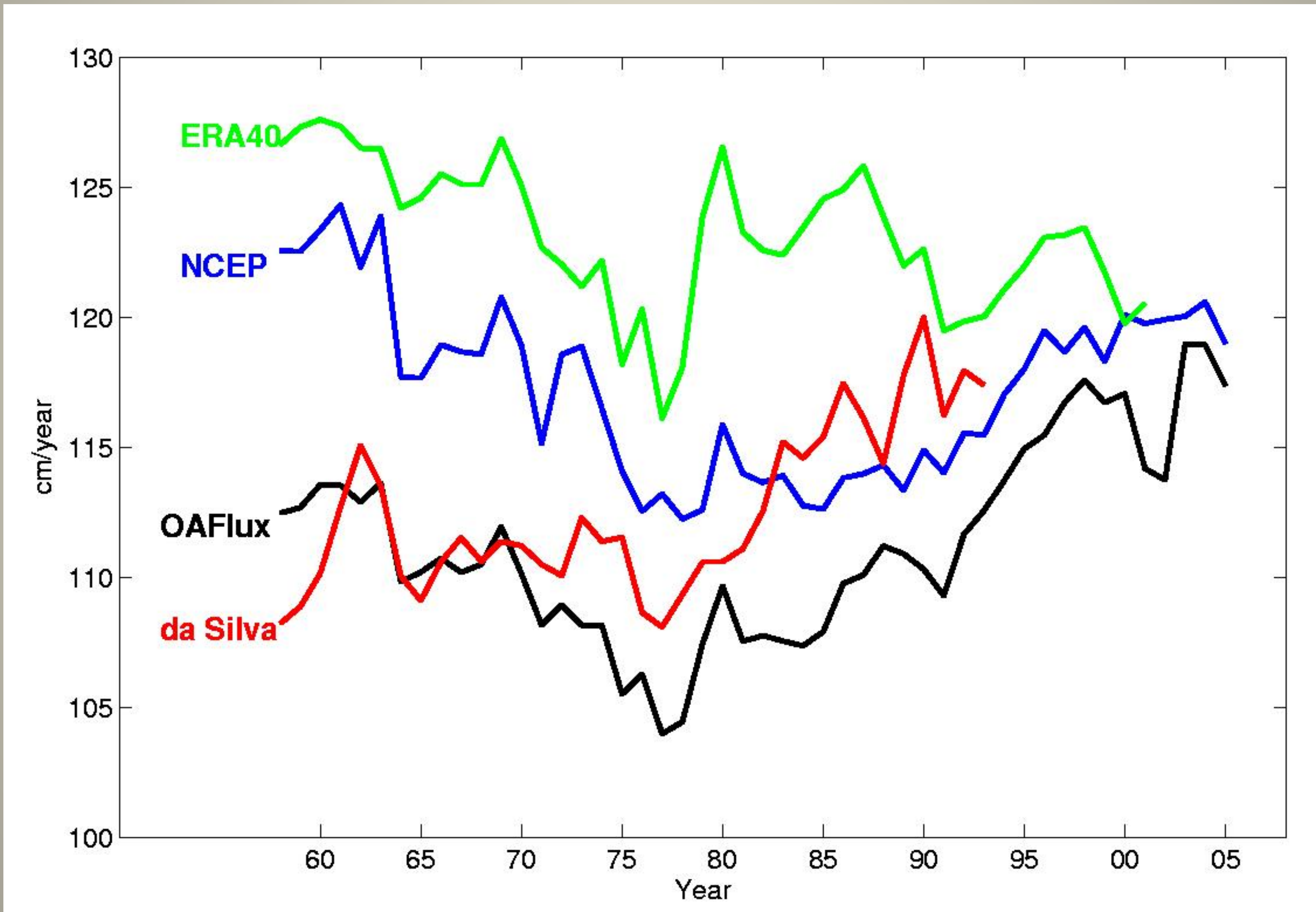
Distribution of Evaporation as function of Temperature (Schanze analysis of Yu and Weller (2007) data.



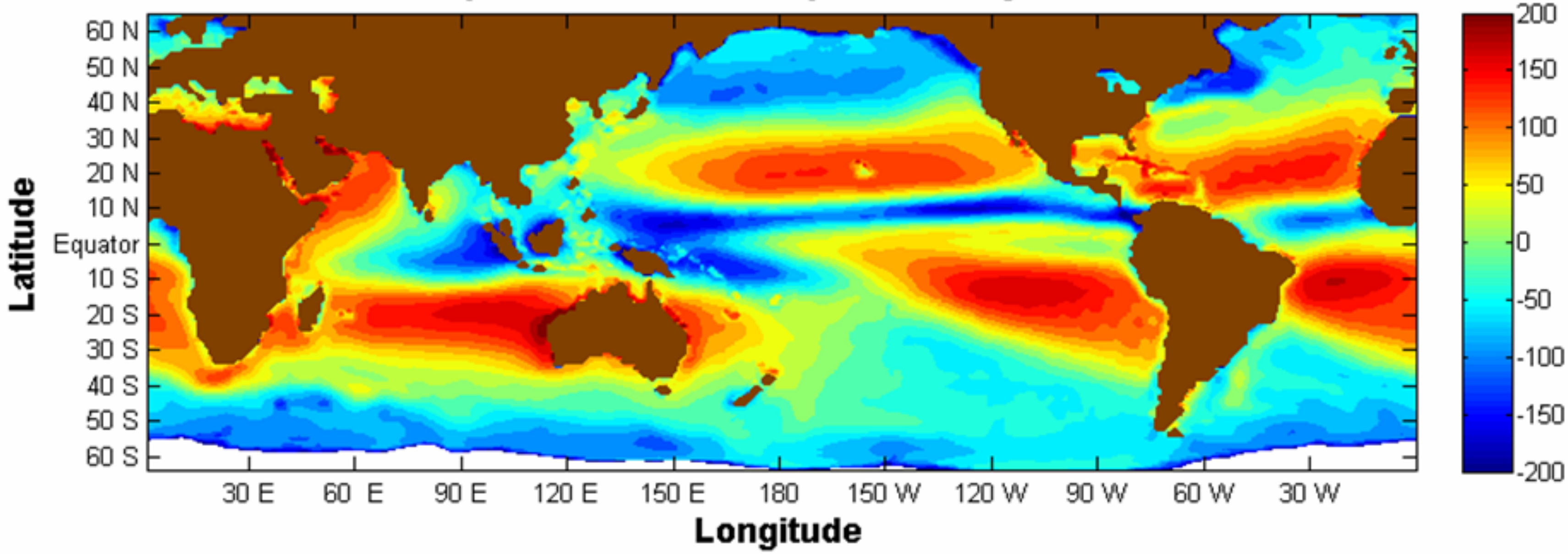
Trends in the Water Cycle: Wentz et al (2007)



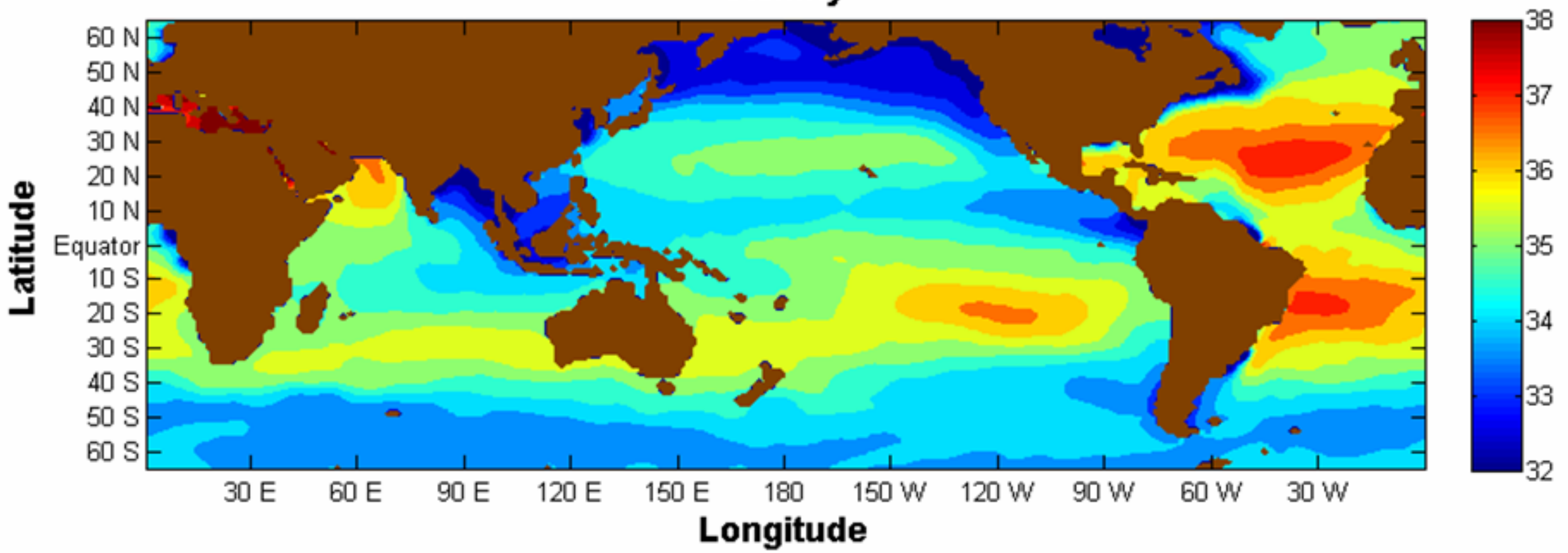
Evaporation Trends in 4 Climatologies (Yu, 2007)



Evaporation Minus Precipitation cm/yr CI = 20

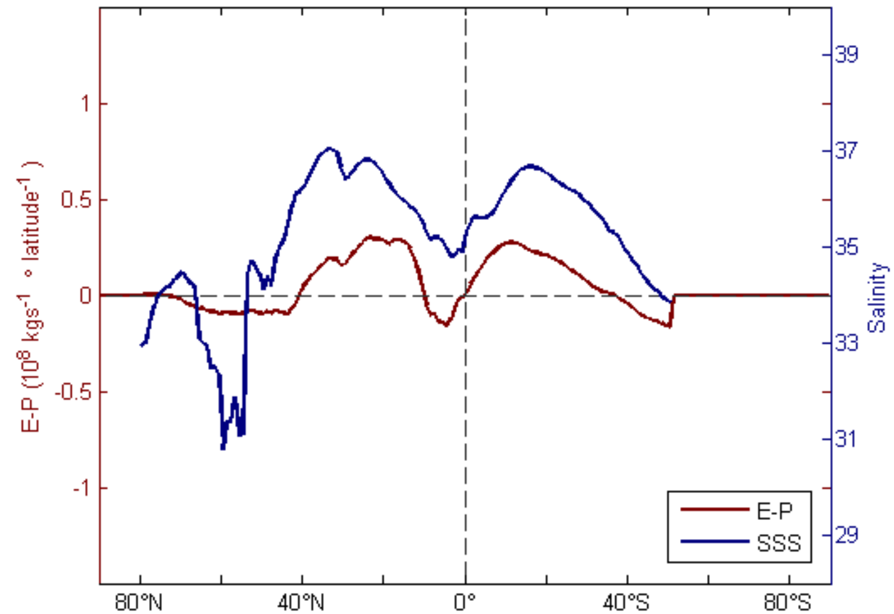


Salinity



Atlantic zonal average

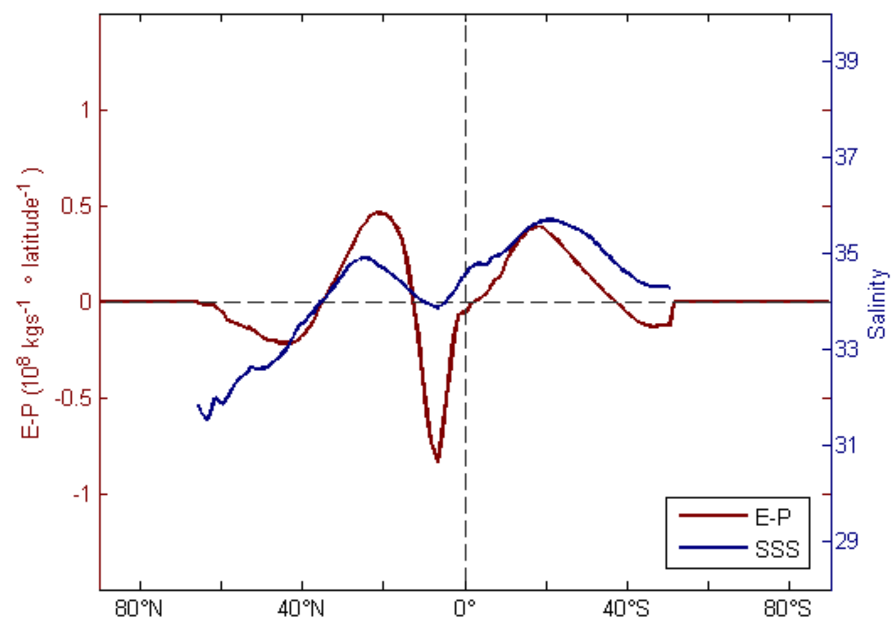
E-P and SSS →



Zonal average E-P and Surface Salinity are well correlated.

Pacific zonal average

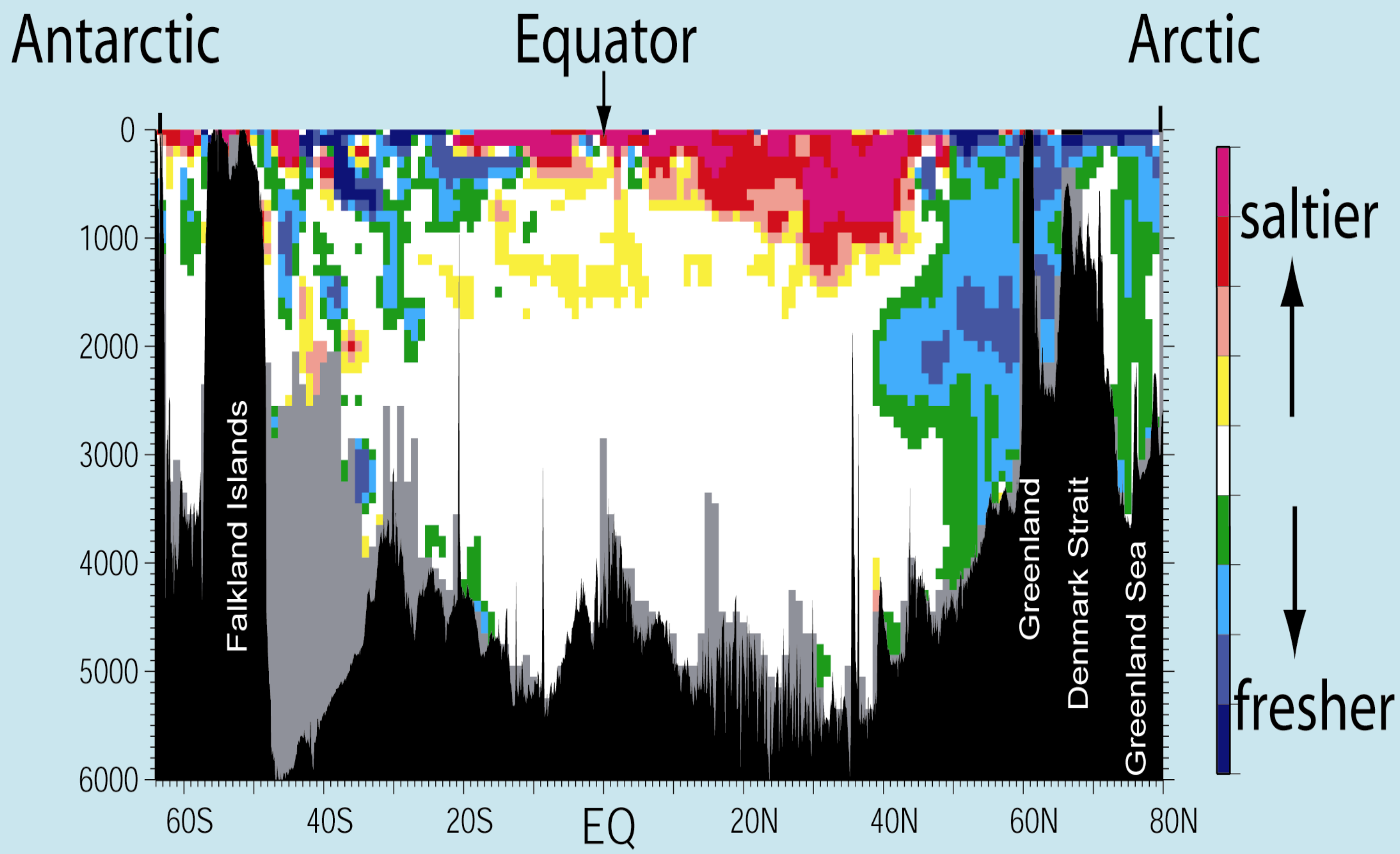
E-P and SSS →

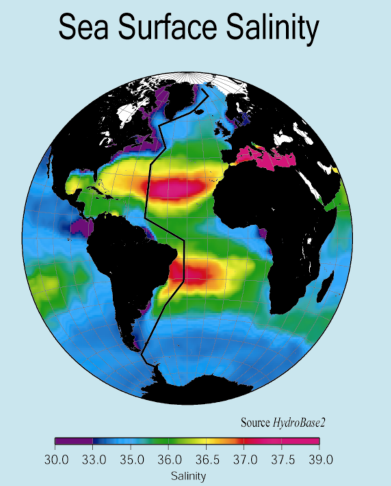


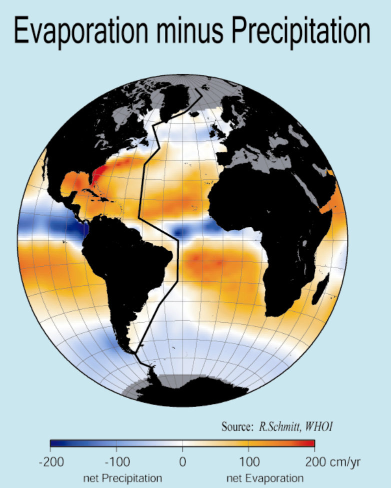
Trends in Atlantic Salinities

Atlantic Ocean Salinity Changes

1990s compared to 1960s





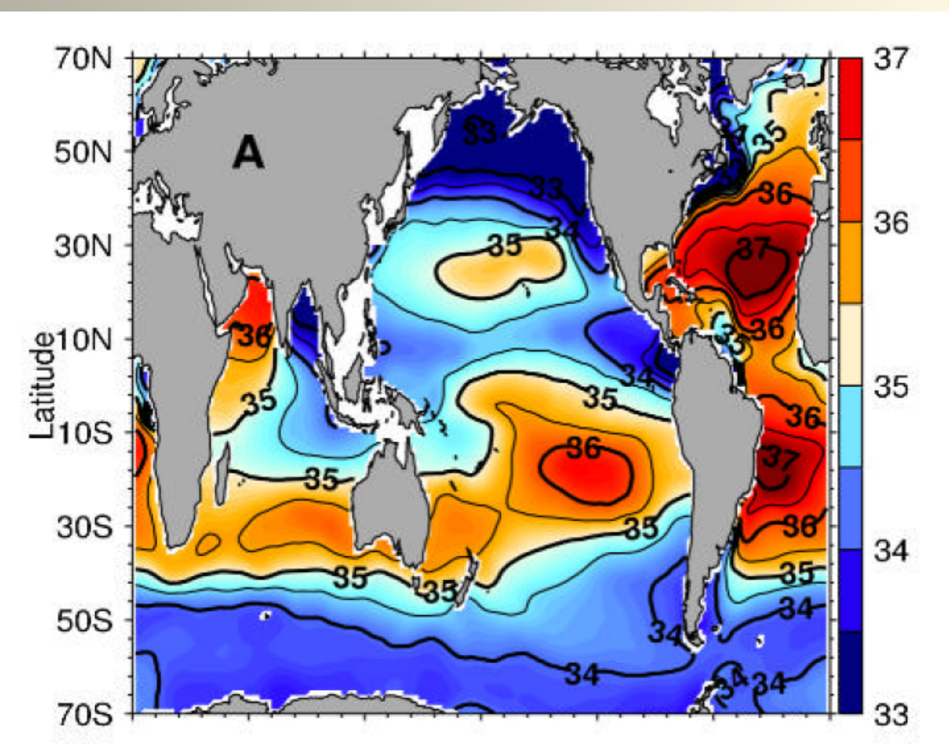


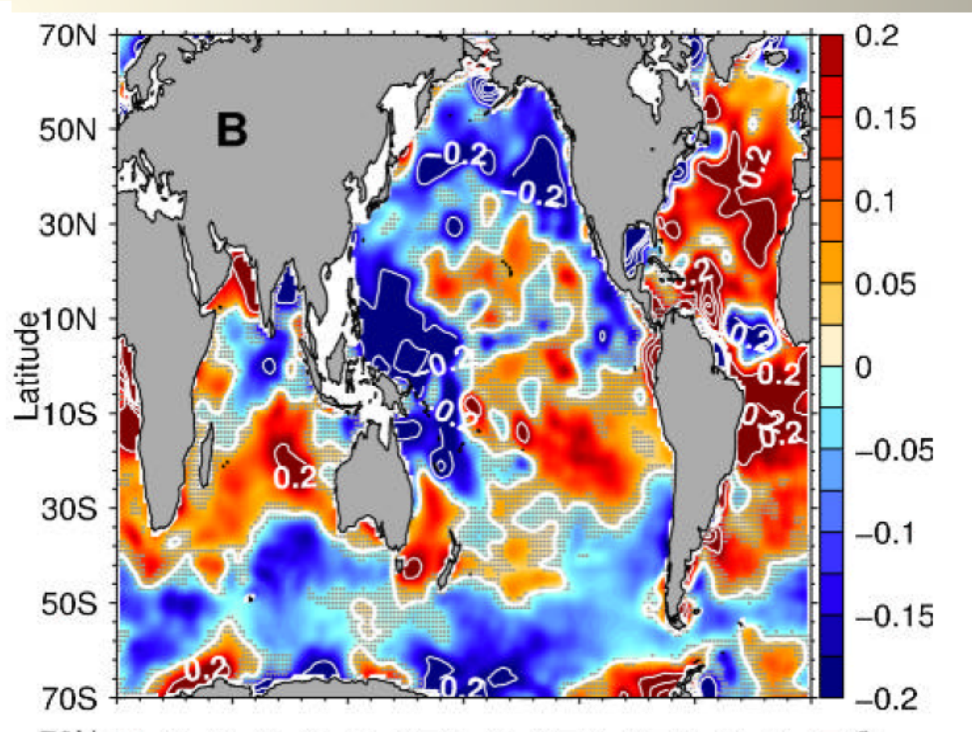
from Curry *et al*. (2003)

Durack and Wijffels, 2010

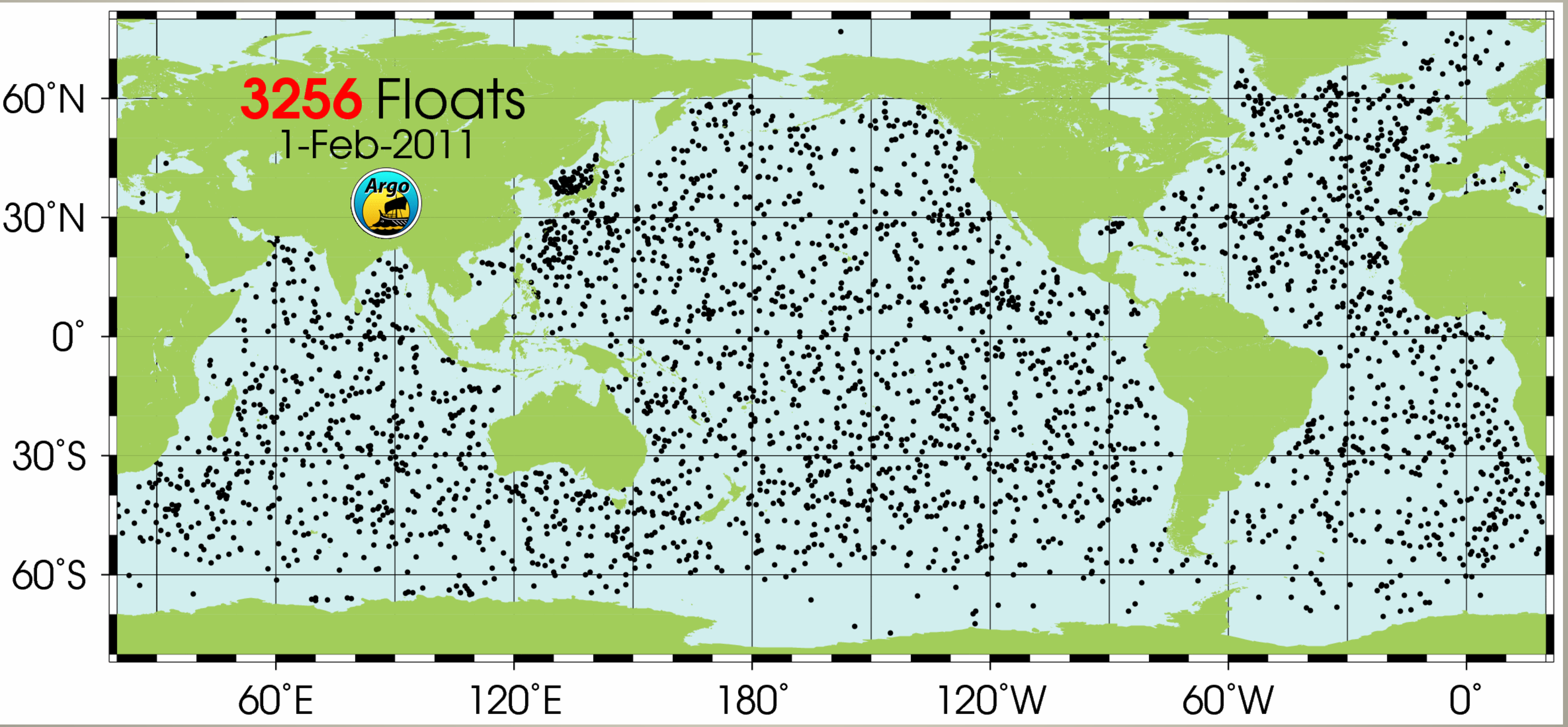
J. Climate

Mean SSS *50 yr trend in SSS*

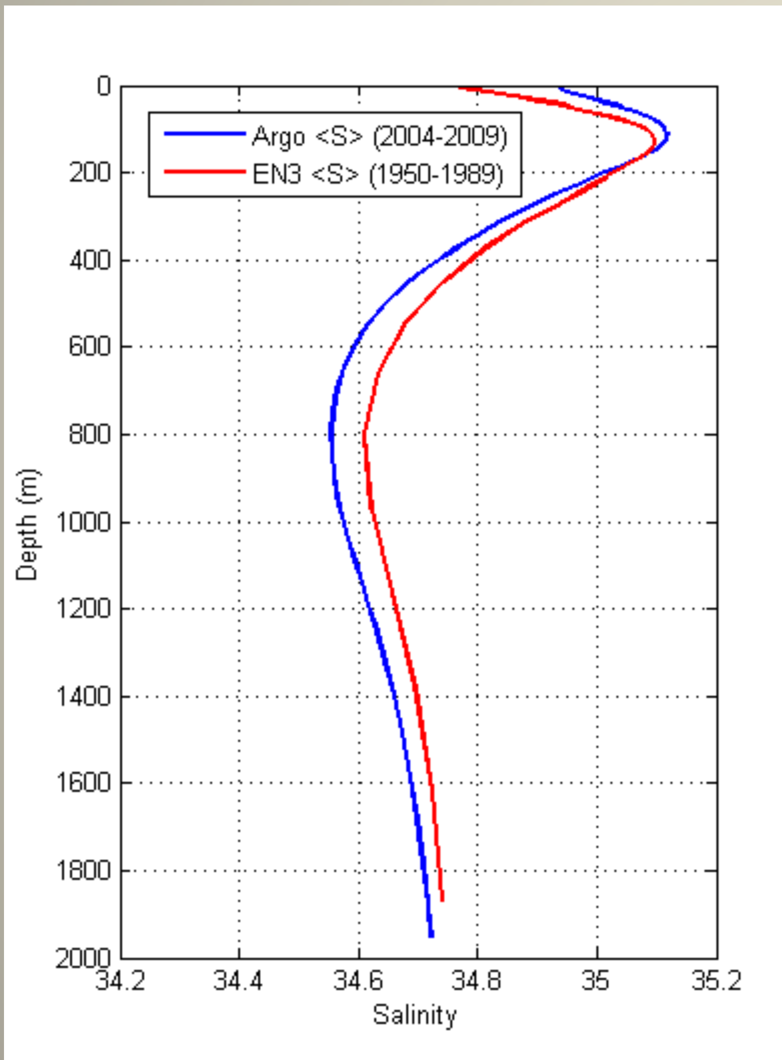


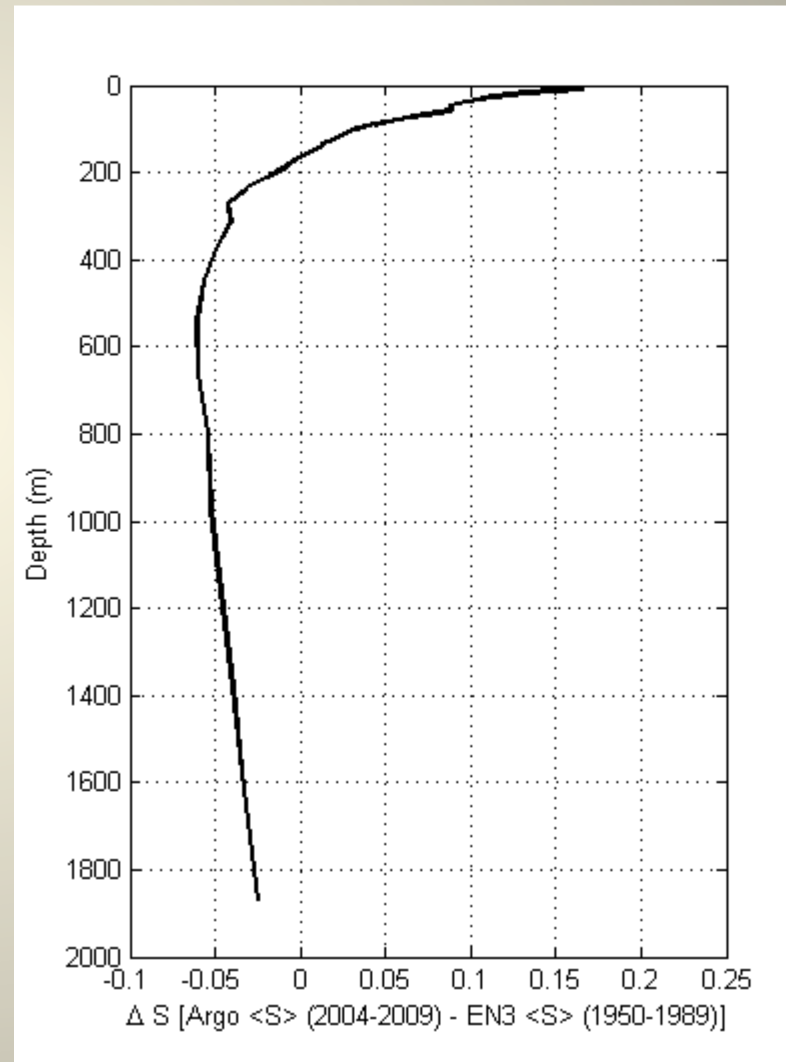


Argo Float Network
(1-Feb-2011)



Global avg. salinity profiles are changing, with S max getting Saltier, S min getting Fresher.





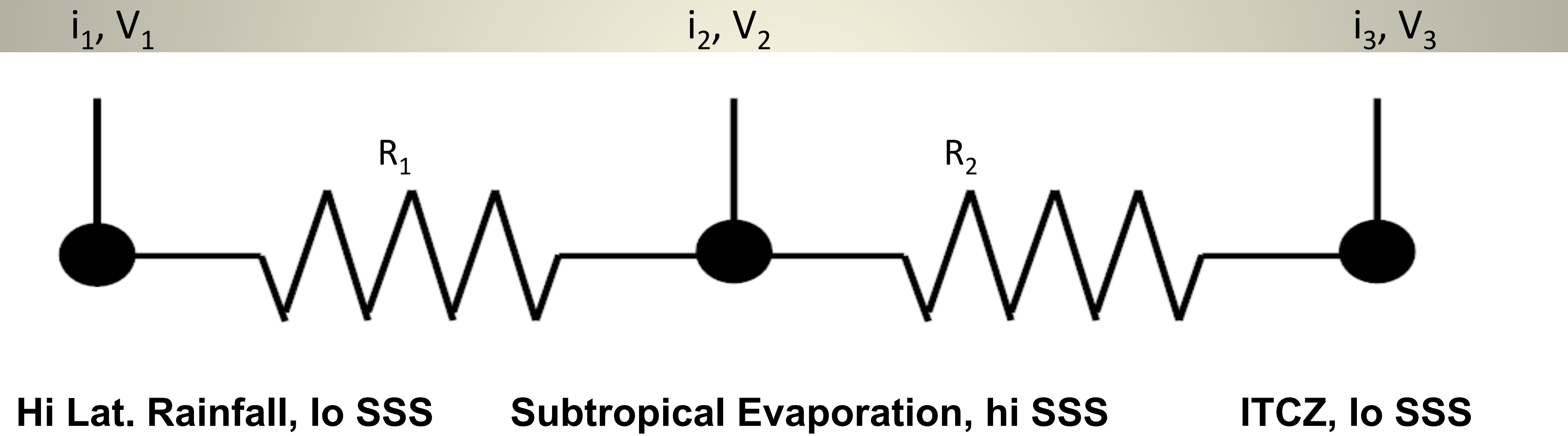
SSS trends indicate significant changes are underway in the global water cycle, (which is primarily an ocean-atmosphere phenomena)

- **High salinity regions getting saltier**
- **Low salinity regions getting fresher**

→Unless ocean mixing and transport is changing, this represents the best evidence we have for an intensification of the global water cycle.

→SSS extrema are of special interest

An electrical analogy: the ocean as resistor network, surface water fluxes as current (i), surface salinity as voltage (V)



Unless Ocean "resistance" has increased, (mixing and transport decreased) higher SSS variance must come from enhanced Evaporation and Precipitation forcing.

How much has the water cycle intensified?

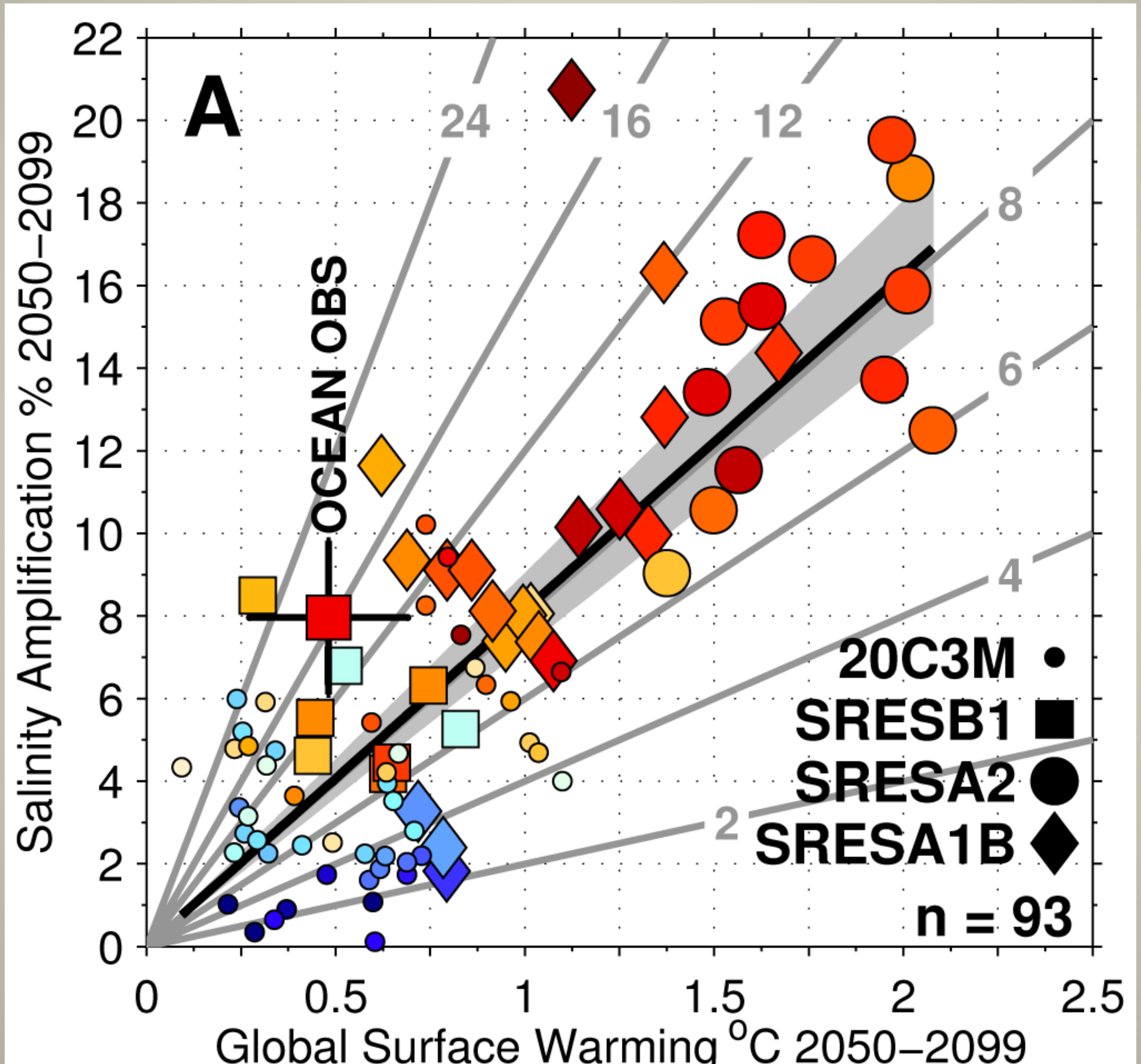
$$i_1 = \left(\frac{V_1 - V_2}{R_1} \right)$$

$$\delta i_1 = \left(\frac{\delta(V_1 - V_2)}{R_1} \right)$$

Unless "R" of the ocean has changed, changes in SSS variance should be proportional to changes in E-P forcing. Durack and Wijffels (2010) report changes of +0.2 in high salinity regions (S=37), -0.2 in low salinity regions (S=33) over 5 decades ($\delta\Delta S/\Delta S \sim 0.1$).

This suggests an intensification of the water cycle of order 2% per decade! This could be even larger if the "R" of the ocean is decreasing due to stronger winds and stronger vertical salt gradients (ie. more salt fingers, Johnson, 2006; ___ and Kearney 2009).

From Paul Durack: model runs



Salinity trends suggest that the Global Water Cycle may be intensifying at 5-8 times faster than predicted in IPCC models!
(Are the radiative effects of water vapor under-predicted? Is ocean warming properly accounted for? Is ocean mixing being inhibited by freshening and warming, or increased by salinification and increasing winds?)

	Data	IPCC Models
Water Vapor	~7%/K (Clausius-Clapeyron)	~7%/K
Winds	Increasing	Decreasing
Evaporation	>10%/K	1.7%/K
Precipitation	~9%/K	1.7%/K
Salinity Contrasts	16%/K	?

Trends in the global water cycle

Simple Clausius-Clapeyron (C-C) thermodynamics suggests water cycle (WC) should increase at ~6-7% per degree of warming, but all models show only a 1-3% increase per degree (a "robust response" - Held and Soden, 2006) This is thought to be due to the diminishing effect on radiative feedback as humidity increases (Stephens and Hu, 2010) and decreasing winds.

Terrestrial data shows no trends (Huntington, 2007; Dai et al, 2009) but Ocean data tends to agree with C-C and not the models! (WC is primarily oceanic..)

Precipitable water: increasing at 1.3%/decade, close to C-C (Durre, et al, 2009; Trenberth, 2005)

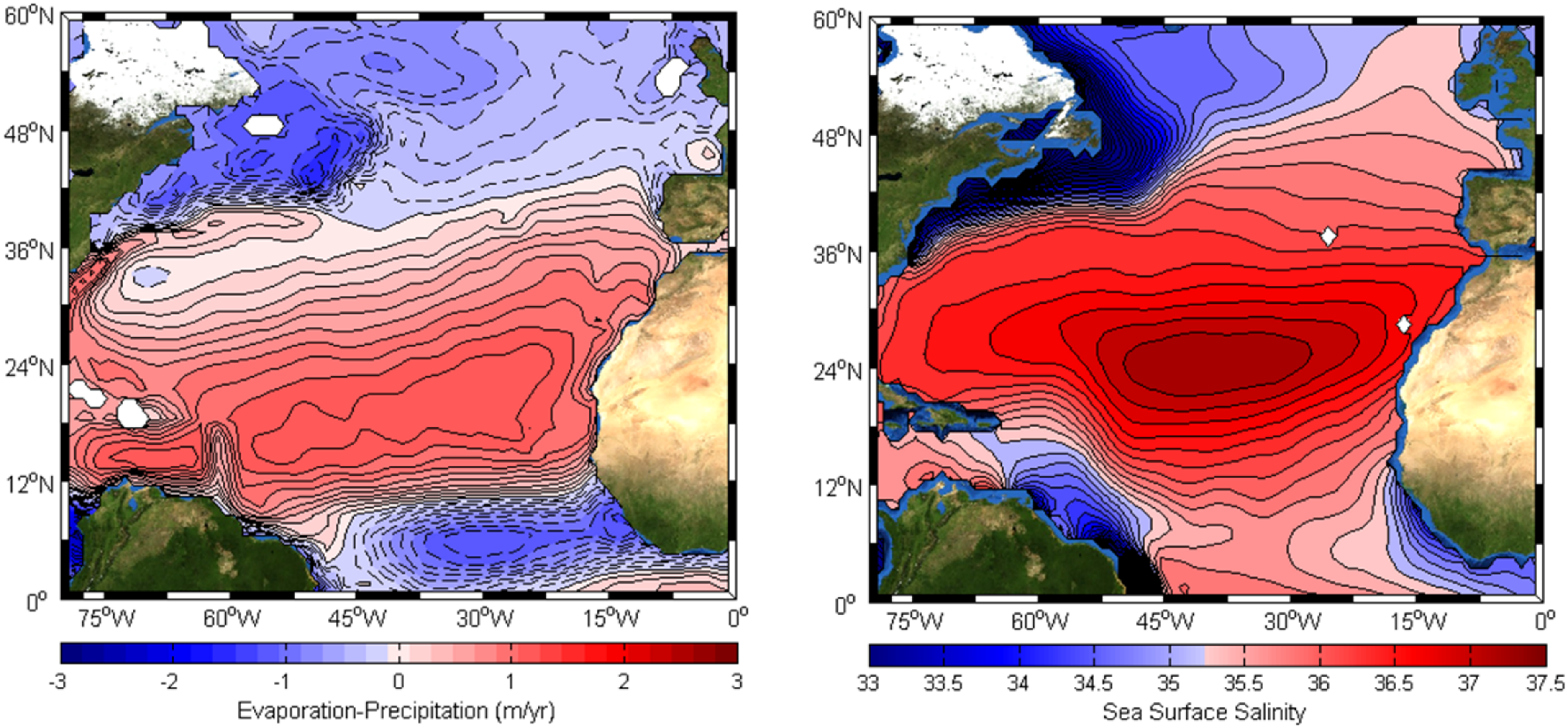
Precipitation: increasing at 1.3%/decade, close to C-C (Wentz, 2007)

Evaporation: Most climatologies show increase, close to C-C (Yu and Weller, 2007). Winds are increasing, not decreasing as the models predict!

Salinity: Salinity contrasts are increasing at >2%/decade, about twice C-C! (Durack and Wijffels, 2010).

E-P and SSS are well correlated (Schmitt, 2008), implying that the ocean is responding to atmospheric forcing to destroy S-variance, and has no mechanism to create S-variance (no internal sources or sinks). The increasing salinity variance is further evidence of a water cycle intensifying at a rate much greater than predicted. It also points out serious problems with the water and energy cycles in IPCC models!

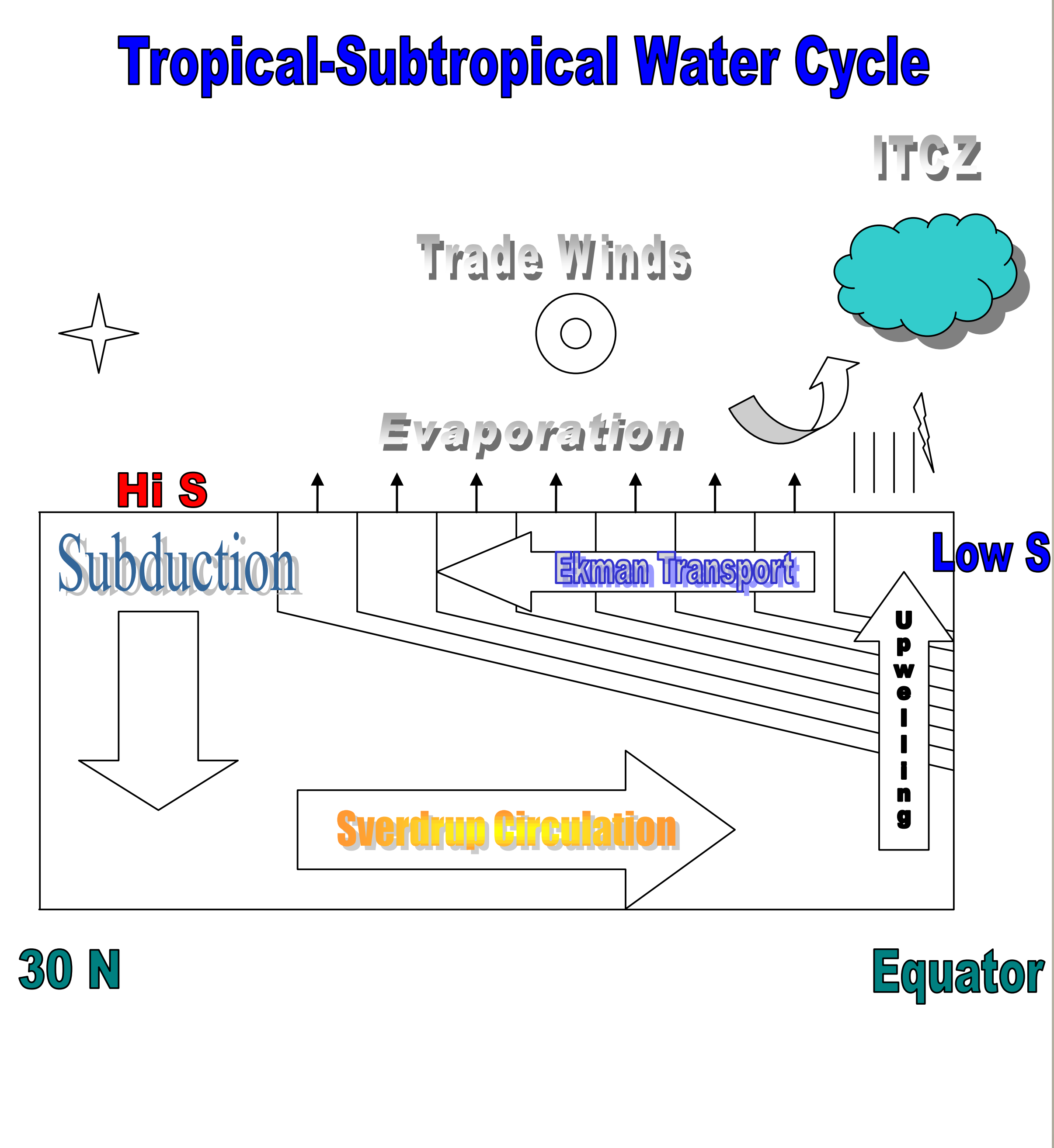
N. Atlantic E-P and SSS are highly correlated



Note: the E-P zero line is close to vegetation/dry land boundary in Africa

An Oceanic Water-cycle

Salinity distributions and oceanic flows reflect the Hadley-cell water cycle in the atmosphere



Summary:

- Salinity appears to be a very sensitive indicator of change in the water cycle.
- Salinity trends indicate WC intensification is <u>much</u> greater than models can explain. This is a key global change issue!
- In order to understand these trends oceanographers have to determine how ocean processes (mixing, subduction) are responding to warming, increasing winds and water cycle intensification. SPURS is well designed to address such physics on diurnal to seasonal time scales.